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Investigation on California Bearing Ratio (CBR) Characteristics of Cement Bound Shredded Tire Geocomposite

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ABSTRACT

This study investigates the California Bearing Ratio (CBR) characteristics of cement bound shredded tire geocomposite. A total of five test series were conducted to investigate the effect of curing day, repeatability of test specimen, effect of curing condition, effect of cement content and effect of rice husk ash (RHA) as cement replacement material on the cement bound shredded tire geocomposite. The CBR test results revealed that higher curing day and cement content increase the CBR of shredded tire geocomposite. On the contrary, a higher RHA content reduces the CBR of the geocomposite.

Introduction

The continuous effort to find lightweight solution for geotechnical engineering works has resulted in development of new materials or geocomposite such as expanded polystyrene (EPS), air mortar foam, coal ash, scrap tire, among others. These geocomposites are commonly applied in embankment construction or as retaining wall backfill. Among these materials, scrap tire has drawn considerably attention as it involves recycling of waste tires in which its disposal has became environment hazards. The generation of waste tires has also grown astronomically with increasing number of vehicles every year. This makes the waste tire an ideal material in which it does not decompose easily with high availability.

In the past, tire wastes have been used as lightweight material either in the form of whole tires, shredded or chips, or in mix with soil. Many studies regarding the use of scrap tires in geotechnical applications have been conducted including laboratory investigations, numerical and physical model and field investigations (Ahmed and Lovell, 1993; Chu and Shakoor, 1997; Humphrey and Tweedie, 2002; Shalaby and Khan, 2005 and among others).

Recently, binder has been introduced into the scrap tire geocomposite. Fattuhi and Clark (1996) and Li et al. (2004) are among the researchers that focus on waste tire-cement mixture. Abdul Naser Abdul Ghani (2003) used shredded tire bound with Ordinary Portland Cement in combination with cement replacement materials such as RHA, SBR and foam to investigate the effectiveness of the geocomposite as compressible layer for retaining structure.

It is found that geocomposite with binder has many advantages over the conventional loose tire-soil mix especially in terms of installation and properties. The bound geocomposite is easy to install as compared to loose tire-soil mix that depends on in-situ compaction and easily affected by vibrations. In addition, the properties of the bound geocomposite can be pre-engineered as compared to the loose tire-soil mix. Therefore, this project investigated the California Bearing Ratio (CBR) of cement bound shredded tire geocompostie to study its potential as roadway construction material.

Raw Materials

The three raw materials used in this study are shredded scrap tire, Ordinary Portland Cement (OPC) and rice husk ash (RHA). The shredded scrap tires used in this study were obtained from commercial suppliers. The shreds contained only rubber component with all steel components removed during the shredding process as shown in Figure 1. Ordinary Portland Cement (OPC) was the selected binder used to bind the shredded tire in this study. The OPC was obtained from commercial suppliers. Rice husk ash (RHA) is a type of industrial by product that has pozzolanic properties. In this study, the RHA was obtained from uncontrolled burning site. The ground RHA was used as partial replacement of OPC in this study.

Figure 1: Shredded Scrap Tire

Peliminary Testing

Prior to CBR testing, preliminary tests were conducted to characterize the shredded tire, namely particle size distribution test and specific gravity test. Figure 2 presents the particle size distribution curve for the shredded tire. On the other hand, a total of five specific gravity tests were conducted reporting the same result of 0.70 that is at least one third lighter of typical soil.

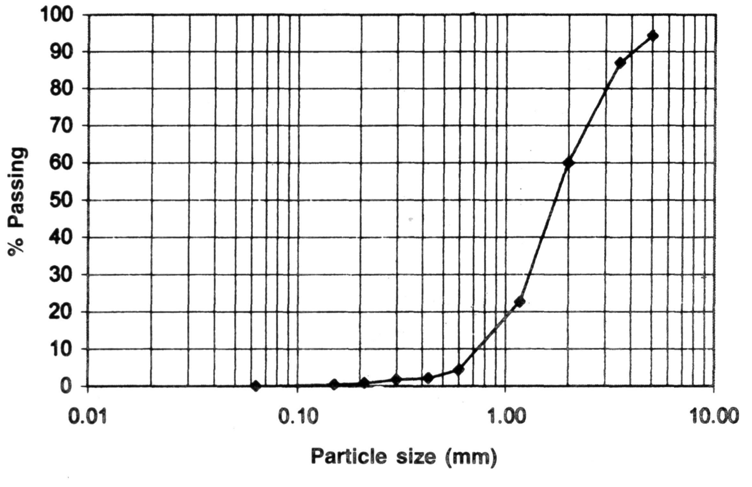

Figure 2: Particle Size Distribution of Shredded Tire

Specimen Preparation

The cylindrical specimens were cast in CBR mould using concrete mixer. To ensure the consistency of the specimen, standardization and control was enforced on casting process and water-cement ratio. The materials were mixed for 15 minute before placing into the CBR mould in three layers. The geocomposite was compacted by vibration (layer by layer) for 10 seconds each layer on a vibrating table. The specimens were then cured at room temperature until day of testing except for Test Series 3. On the other hand, a fix water-cement ratio (w/c) of 0.5 was adopted for all specimens as Abdul Naser Abdul Ghani (2003) disclosed that higher water-cement ratio might cause segregation problem. Figure 3 shows the shredded tire geocomposite specimen.

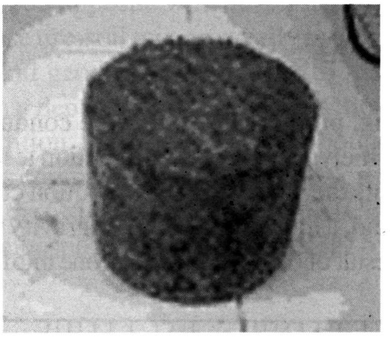

Figure 3: Shredded tire geocomposite specimen

One way to assess the consistency of the geocomposite is by measuring the bulk densities of the specimen. Table 1 presents the bulk densities of the shredded tire geocomposite measured at different curing days of 1, 3, 7, 14, 21 and 28 days. It is observed that the bulk densities ranged from 1.10 to 1.14 g/cm^3. The average bulk density is therefore about 1.11 g/cm^3 The biggest difference between these specimens is computed to be 4.5%, which is less than 5% indicating high consistency and repeatability of specimen.

Test Programme

Table 2 shows the mix design and summary of CBR tests conducted in this study. A total of five test series investigating different mix designs of

Table 1: Bulk Density of Cement Bound Shredded Tire Geocomposite

Curing Day	Bulk Density (g/cm^3)
1	1.14
3	1.12
7	1.11
14	1.11
21	1.10
28	1.10

Table 2: Mix Design and Summary of Laboratory CBR Test

No	Series	Test	Mix Design	CBR (%)	Remarks
1	Investigation on effect of curing day	1.1	1:1 OPC/Shredded tire 1 day	12.72	Higher curing day higher CBR
		1.2	1:1 OPC/Shredded tire 3 days	35.04	
		1.3	1:1 OPC/Shredded tire 7 days	41.22	
		1.4	1:1 OPC/Shredded tire 14 days	43.10	
		1.5	1:1 OPC/Shredded tire 21 days	50.52	
		1.6	1:1 OPC/Shredded tire 28 days	55.65	
2	Control specimen and repeatability test	2.1	1:1 OPC/Shredded tire 1 day	12.72	3-day curing day is selected
		2.2	1:1 OPC/Shredded tire 1 day	11.75	
		2.3	1:1 OPC/Shredded tire 3 days	35.04	
		2.4	1:1 OPC/Shredded tire 3 days	34.30	
		2.5	1:1 OPC/Shredded tire 7 days	41.22	
		2.6	1:1 OPC/Shredded tire 7 days	41.07	
3	Investigation on effect of curing condition*	3.1	1:1 OPC/Shredded tire size (room temperature)	35.04	14.82% CBR reduction for water soaked condition
		3.2	1:1 OPC/Shredded tire size (soaking under fresh water)	30.49	
4	Investigation on effect of cement content*	4.1	0.6:1 OPC/Shredded tire	3.92	Higher OPC higher CBR
		4.2	0.8:1 OPC/Shredded tire	25.07	
		4.3	1.0:1 OPC/Shredded tire	35.04	
		4.3	1.2:1 OPC/Shredded tire	39.14	
		4.4	1.4:1 OPC/Shredded tire	50.00	
5	Investigation on effect of RHA*	5.1	0% RHA replacement + OPC **	35.04	Higher RHA lower CBR
		5.2	5% RHA replacement + OPC **	12.35	
		5.3	10% RHA replacement + OPC **	9.60	
		5.4	15% RHA replacement + OPC **	6.29	
		5.5	20% RHA replacement + OPC **	1.90	

* Test series 3-5 adopt specimens cured at 3 days
** Test series 5 adopts specimens with 1:1 OPC/shredded tire ratio

cement bound shredded tire geocomposite were conducted. The designs were varied based on effect of curing day, repeatability of test specimen, effect of curing condition, effect of cement content and effect of RHA content.

Results

Investigation on Effect of Curing Day

Figures 4 shows the investigation of effect of curing day on CBR of the cement bound shredded tire geocomposite. These specimens were cured in room temperature for 1, 3, 7, 14, 21 and 28 days. It is observed that CBR increases with increasing curing duration. The highest increment of CBR is 337.55% at 28 day when compared to the control specimen. Similar trend was also observed by Abdul Naser Abdul Ghani (2003) on compressive strength of cement bound shredded tire geocomposite.

Based on this investigation, it is decided that curing day of 3 days is to be adopted in subsequent test series. The main consideration in this selection is that road construction is usually rapid and in the time zone of less than 3 day. 1 day is not being considered as the specimen is barely cured and the CBR value observed is way too low. Therefore, 1:1 OPC/ shredded tire at 3-day with CBR of 35.04% is selected as the control specimen for purpose of comparison and reference.

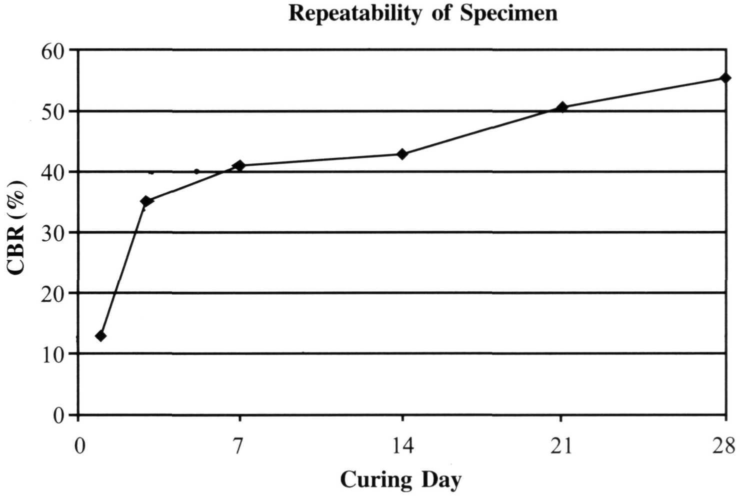

Figure 4: Relationship between CBR and Curing Day

Repeatability of Test Specimen

To test the repeatability of test specimen, two identical CBR tests were repeated for 1-day, 3-day and 7-day specimen respectively. Repeatability tests are required in order to ensure the consistency and reliability of the test results. Figure 5 shows the repeatability of specimens at 1, 3 and 7 curing day. The difference is in the order of 0.36 – 8.25% indicating acceptable repeatability of less than 10%. It is observed that the difference decreases with increasing curing day indicating higher stability and consistency. This further reinforces the decision of selecting 3-day specimen in subsequent testing.

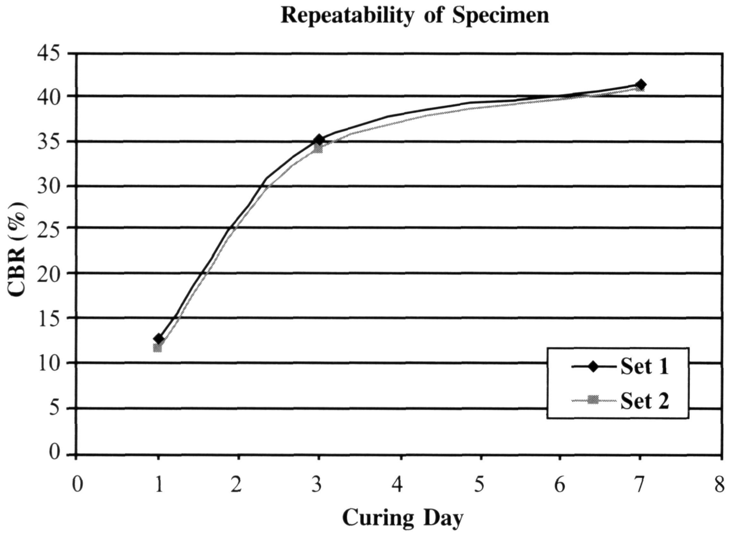

Figure 5: Repeatability of Specimen at 1, 3 and 7 Days

Investigation on Effect of Curing Condition

At this stage, the geocomposite were cured in two conditions, namely at room temperature and submersed under fresh water to simulate weathering effect upon application of the geocomposite in roadway construction. Curing at room temperature is the ideal condition/control specimen whereas curing under fresh water signifies the worst weathering condition with the geocomposite constantly under water/heavy rain. They were left in these conditions for 3 days. The CBR for specimen in fresh water condition was 30.49% as compared to the control specimen at room temperature with CBR of 35.04% as shown in Figure 6. This indicates a reduction of 14.92% in CBR when subject to constant water soaking of 3 days.

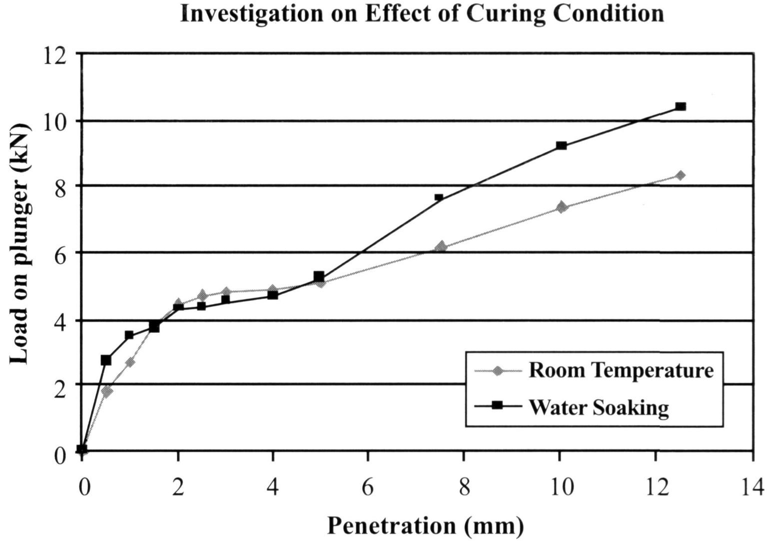

Figure 6: A Lower CBR for Water Soaked Specimen

Investigation on Effect of Cement Content

Figure 7 shows the relationship between OPC content and CBR of the shredded tire geocomposite at 3-day curing at room temperature. The OPC content was increased in 0.2 intervals from 0.6 to 1.4 times of shredded tire. It is observed that the CBR value varies from 3.92 % to 50% with shredded tire to OPC ratio of 0.6 : 1 to 1.4 : 1 respectively. This observation indicates that increasing OPC content will increase CBR value of the shredded tire geocomposite. In another word, increasing shredded tire content will reduce CBR value. Similar relationship was also observed by other researchers (Fattuhi and Clark, 1996, Abdul Naser Abdul Ghani, 2003) on compressive strength of cement-tire mixture.

Investigation on Effect of RHA

Various content of rice husk ash, RHA (5, 10, 15 and 20%) were used to replace the OPC in the control specimen, namely 1:1 OPC : shredded tire at 3 day mix. Figure 8 shows the relationship between RHA content with CBR. A decreasing trend in CBR is observed with increasing RHA content. It is observed that cement replacement of RHA up to 20% reduce the CBR to only 1.9%. The difference between the highest and lowest CBR is 94.58%. In view of this, RHA might not be a good

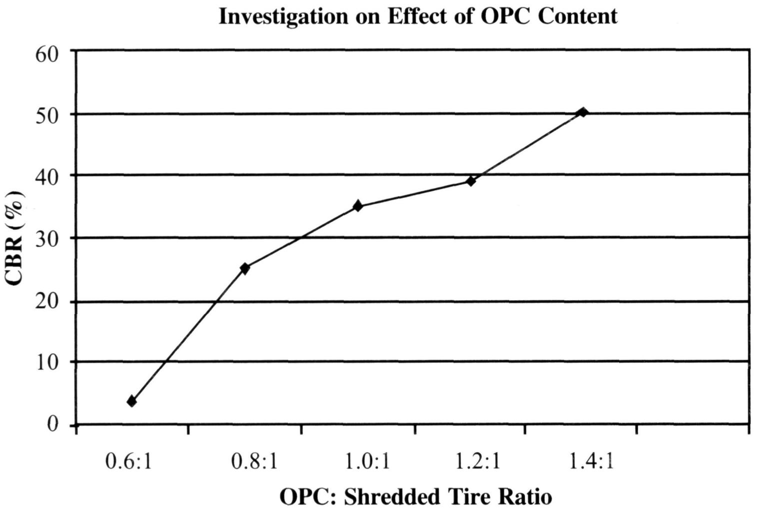

Figure 7: An increasing CBR with Increasing OPC Content in Geocomposite

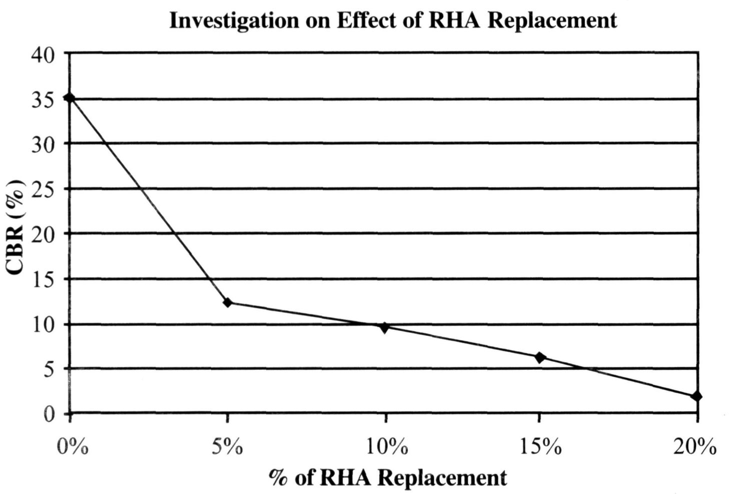

Figure 8: A Decreasing CBR with Increasing RHA Replacement in Geocomposite

replacement material in roadway construction as it reduces the CBR. However, RHA replacement might be welcomed in application of shredded tire geocomposite as retaining wall backfill as it increases the compressibility of the geocomposite.

Discussion

To evaluate the suitability of application of the cement bound shredded tire geocomposite in flexible pavement, the control specimen was considered, namely 1:1 OPC/shredded tire at 3-day with CBR of 35.04%. Considering its application as the sub base course in flexible pavement, it might be used to replace both sand and laterite having CBR value more than 20% and crushed aggregate having CBR value more than 30% based on JKR Arahan Teknik (Jalan) 5 /85. However, the cost implication is unknown and requires more justification.

Conclusions

This study investigates the California Bearing Ratio (CBR) characteristic of cement bound shredded tire geocomposite. A total of five CBR test series were conducted to investigate the effect of curing day, repeatability of test specimen, effect of curing condition, effect of cement content and effect of RHA content. A standardized casting process was devised and a fixed water-cement ratio of 0.5 was adopted. It is observed that the shredded tire has a specific gravity of 0.70. The bulk density of the shredded tire geocomposite was found to be about 1.11 g/cm^3. Both values indicate the geocomposite is much lighter than soil. The CBR test results revealed that higher curing day and cement content increase the CBR of shredded tire geocomposite. Repeated testing on 1-day, 3-day and 7-day specimens were conducted reporting acceptable repeatability of less than 10%. A reduction of 14.92% in CBR was observed when the geocomposite was subjected to constant water soaking of 3 days. It is also observed that a higher RHA content reduced the CBR of the geocomposite.

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